TESTING OF POWER LINE APPARATUS FOR RADIO NOISE

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Summary

This paper discusses a simple and practical method of testing power line apparatus for radio noise. This type of testing is qualitative in nature and is designed for use by power companies and other electric system operators as well as by apparatus manufacturers. The apparatus to be tested is energized from a variable voltage source and slowly brought up to and beyond operating voltage. A portable, battery-powered radio receiver is placed nearby to detect the ionization threshold. If this threshold lies above a predetermined voltage the apparatus may be considered satisfactory from a radio influence standpoint.

The scope of this paper is limited to the testing of power line apparatus and pole top assemblies utilizing distribution voltages up to and including 14.4/24.9 kv grounded wye.

Introduction

The ideal method of determining the radio influence of power line apparatus is to take quantitative measurements of radio influence voltage generated within the apparatus in question. However, such measurements are sometimes extremely difficult to obtain and reproduce. Complex measurements are required and persons skilled in this specialized field must be utilized. Radio influence measuring techniques(1) and equipment(2) have long been under discussion in the profession, and the question of standardization has always been a controversial one.

Then there is the question of acceptable radio influence voltage limits. Manufacturers' standardization organizations and urban system operators are prone to set arbitrary radio influence voltage limits at higher levels than the arbitrary levels acceptable to many operators of electric distribution systems. For example, the tolerable ambient radio noise level in an urban area is much higher than that in a rural area where radio and TV signals are weak. The rapid spread of television throughout the United States has focused attention on power line noise, particularly in rural areas, and the need for operating extremely quiet distribution lines increases day by day.

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This paper describes a qualitative method of testing that can be used by system operators and manufacturers alike. It might be termed the Ionization Threshold Method. Apparatus which passes this test may be considered completely free from objectionable radio and television interference even in fringe areas of reception.

Ionization Threshold

The ionization threshold may be defined as the lowest voltage level at which readily detectable ionization occurs in a piece of apparatus such as in a bushing, a lightning arrester, a distribution transformer or in a pole top assembly of apparatus and hardware. Ionization is the mechanism through which radio influence voltage is generated in power line apparatus and assemblies. Figure 1 illustrates the relation of ionization threshold to radio noise in power line apparatus. Radio influence voltage will not be present if ionization is not present. Thus, if a piece of apparatus is operated at a voltage level below its ionization threshold, it will be free from radio noise. To state this axiom another way, if the ionization threshold of a piece of apparatus lies above the operating voltage, the apparatus will be free from radio noise. Fortunately, the ionization threshold may be detected quite easily with simple low cost test equipment. It is also fortunate that power line apparatus, in which this ionization threshold lies well above the operating voltage, is readily available from many sources of supply. Such apparatus is available without payment of premium prices. This includes apparatus up to and including the 25 kv class. The availability of such apparatus makes this ionization threshold method a practical and effective means of testing apparatus for radio noise. The ionization threshold may thus be considered a good and reliable index to the acceptability of power line apparatus from a radio influence standpoint. The ionization threshold method of testing is also a practical inspection and maintenance tool. A marked lowering of the ionization threshold has been found to be a good indicator of incipient failures in insulators, arresters, bushings and transformer windings.

Test Equipment

The test equipment needed consists essentially of the following items:

a. Noise-free high voltage transformer.
b. Variable voltage control unit.
c. Low-pass filter (not always necessary).
d. Battery-powered radio receiver.

A block diagram of the test setup is shown in Figure 2.

The noise-free transformer is a small distribution transformer capable of delivering a radio-noise-free test voltage up to approximately 120 percent of the operating voltage of the apparatus to be tested. Such a transformer may be either a single bushing or two bushing type. In any event, one end of the high voltage winding should be grounded. Figure 3 illustrates three types of transformers used by the authors for this purpose.

The variable voltage control unit consists of a variable autotransformer, voltmeter, a circuit breaker and two "voltage on" warning lamps. One lamp indicates that the input to the control unit is energized and the second lamp indicates that the output circuit is energized. This double safety feature is deemed desirable in view of the fact that lethal voltages and currents are involved in the test setup. An instantaneous-trip circuit breaker set as low as possible is an added safety feature. It also serves as an on-off switch. The control unit operates from a 115 volt, 60 cycle AC supply and provides a variable voltage to the noise-free transformer. The range of the voltage is 0-135 volts. The voltmeter is connected across the output of the variable transformer and is calibrated in terms of the noise-free transformer high voltage output. While this method of measuring the high voltage is not precise, it is sufficiently accurate for the purpose intended. Figure 4 is a circuit diagram of the control unit used by the authors. Figure 5 is a photograph of the control unit.

When testing is to be done in buildings which have noisy electric supply circuits, the use of well grounded low-pass filters in both sides of the supply line leading into the control unit will prove helpful. In buildings where electrical noise is extremely high, the use of a screened room may be necessary.

Any type of battery-powered radio receiver, including an automobile radio, may be used. Good results may be obtained by using a whip type antenna approximately 3 feet long. The use of battery power rather than a 115 volt AC supply is necessary to minimize noise pickup from the power supply line. Figure 6 illustrates two types of portable receivers that have been used successfully. The sensitivity of the receiver used will not appreciably affect the detection of the ionization threshold. This is best illustrated in Figure 7 which shows the effect of receiver sensitivity upon detection of the ionization threshold of a pin-type insulator.

The exact location of the radio receiver with respect to the apparatus under test is not critical within reasonable limits. This is illustrated in Figure 8 which shows the effect of receiver location upon detection of the ionization threshold of a lightning arrester.

Test Procedure

Apparatus to be tested should be arranged on a stub pole or other suitable supporting medium. Spacings should be maintained with respect to grounded hardware, and if possible, insulator ties should be made and ground leads should be dressed and connected exactly in the same manner as is done under actual operating conditions. The tank of the test transformer should be connected to the grounded side of the 115 volt supply line.

The high voltage lead of the transformer is connected to the apparatus to be tested and the battery-powered radio is set up within 2 feet of this high voltage lead which acts as a radiator for any radio noise generated in the apparatus. The test assembly is then energized and voltage is slowly raised until the ionization threshold is reached. Voltage should be raised and lowered several times to accurately detect the ionization threshold.

Care must be exercised to prevent corona formation by dressing the ends of conductors and other sharply pointed conducting parts in the test assembly. Otherwise ionization may occur in the test assembly at a lower voltage than in the apparatus being tested. All hand tools or other metallic objects capable of picking up an electrostatic charge should be removed from the immediate vicinity of the test setup. The radio receiver itself should be supported on an insulated platform such as a wooden table, or it may be bonded to the test setup ground.

Most apparatus will exhibit a sudden transition into an ionization state, and the ionization threshold is thus easily recognizable. Curve A of Figure 9 is a typically shaped radio-noise curve plotted as a function of energizing voltage. It will be noted from this curve that for energizing voltages below the ionization threshold there is no perceptible radio noise. At the threshold point radio noise appears and then rapidly increased in intensity as the energizing voltage is raised.

Occasionally a piece of apparatus will not exhibit the above characteristics but will increase its radio noise output gradually as the energizing voltage is raised. Such an example is shown in Curve B of Figure 9. Apparatus exhibiting this characteristic is more difficult to evaluate on a qualitative basis.

The testing of small distribution transformers (10 kva and under) by the ionization threshold method is a relatively simple procedure. The output leads of the control unit are connected directly to the low voltage winding of the transformer under test and a 3 foot wire whip with a small loop at the upper end is connected to the high voltage bushing to act as a radiator. The other end of the high voltage winding is grounded to the transformer tank. The radio receiver is placed within 2 feet of this radiator and the transformer is energized from the low voltage side. The voltage is brought up slowly while the operator listens to detect the ionization threshold. The transformer should be energized at full operating voltage for a period of at least ten minutes while listening for noise. Some types of insulation defects do not show up immediately but manifest themselves after several minutes of operation. A photograph of a transformer test setup is shown in Figure 10. The transformer may be considered satisfactory from a radio noise standpoint if the ionization threshold lies somewhat above the normal operating voltage.

Transformer bushings may be tested for radio noise by first removing the bushing and cover assembly from the tank and then energizing the bushing, with cover grounded, from the noise-free high voltage source. This test setup is shown in Figure 11.

Pole top assemblies may be tested for radio noise by rigging a stub pole with the pole top assembly exactly as it would exist under operating conditions. The live parts are energized from the noise-free high voltage source and the ionization threshold may then be detected in the manner previously described. Tests of pole top assemblies should also be made under simulated wet weather conditions by thoroughly drenching the pole and other wood members involved. A test setup of a pole top assembly is shown in Figure 12.

Examples of Test Results

Figures 13 and 14 are tabulations of typical test results of various types of apparatus tested by the ionization threshold method. Items were considered acceptable when the threshold voltage was at or above 110 per-cent of line-to-ground operating voltage.

References

1. Methods of Measuring Radio Noise, EEI G9, NEMA #107, a joint publication of Edison Electric Institute and National Electric Manufacturers Association (New York, N. Y.), 1940.

2. Proposed American Standard Radio Noise Meter, ASA C63.2, American Standards Association (New York, N. Y.), 1950.

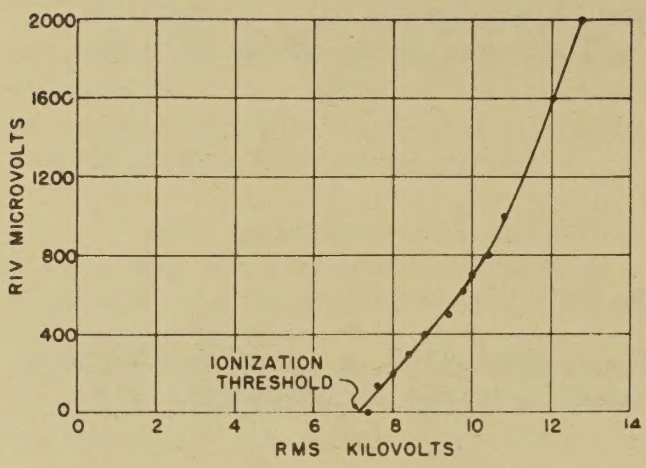

Figure 1. A typical example of radio influence voltage occurring in a piece of power line apparatus as a function of energizing voltage. Note the ionization threshold.

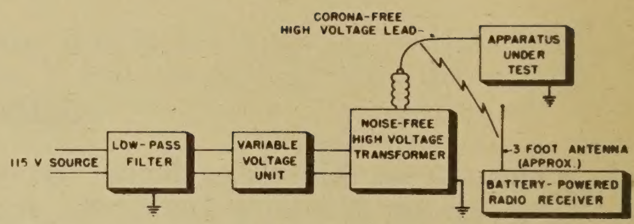

Figure 2. Block diagram of test setup.

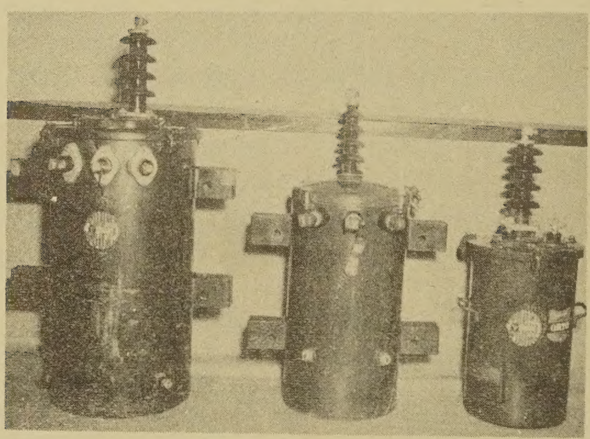

Figure 3. Three types of radio-noise free transformers used as high voltage sources.

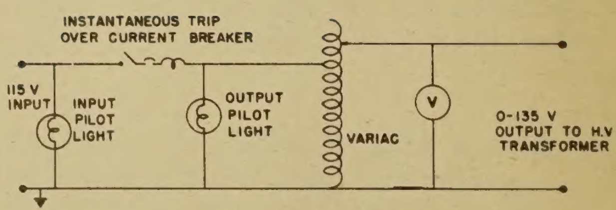

Figure 4. Circuit diagram of variable voltage control unit.

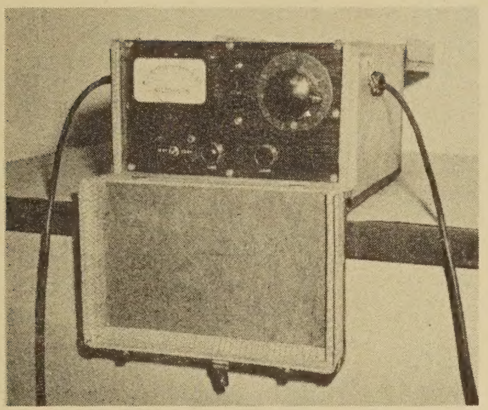

Figure 5. Variable voltage control unit contained in a carrying case for convenience in handling in the field.

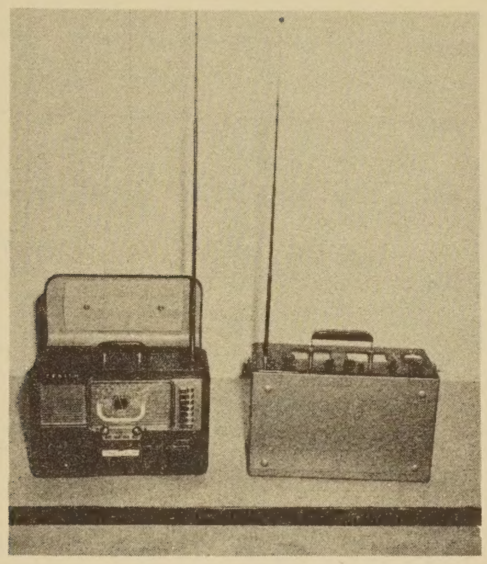

Figure 6. Two types of portable receivers used successfully in detecting ionization threshold.

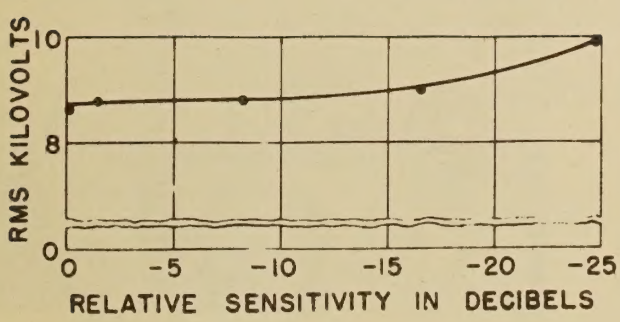

Figure 7. Threshold voltage detection as a function of receiver sensitivity.

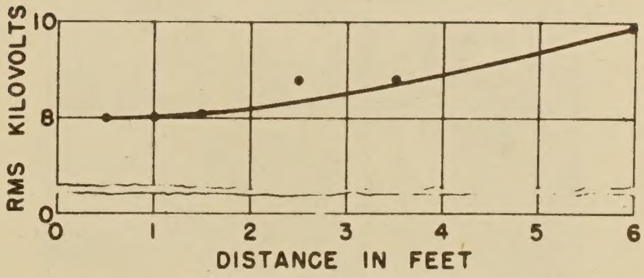

Figure 8. Threshold voltage detection as a function of distance between receiver and apparatus under test.

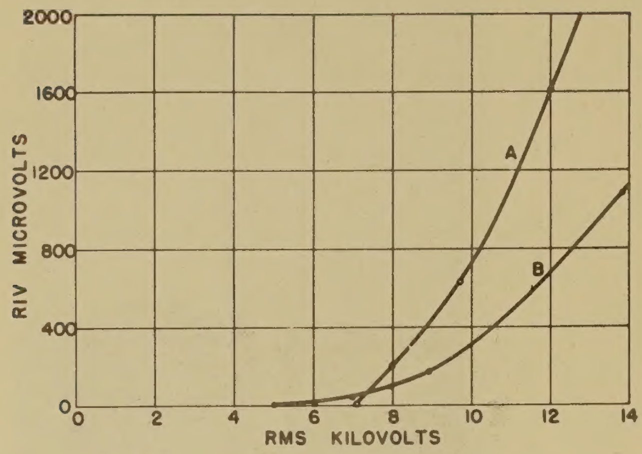

Figure 9. Examples of radio influence voltage occurring in power line apparatus as a function of energizing voltage. The steep-sloped type of Curve A occurs much more frequently than Curve B.

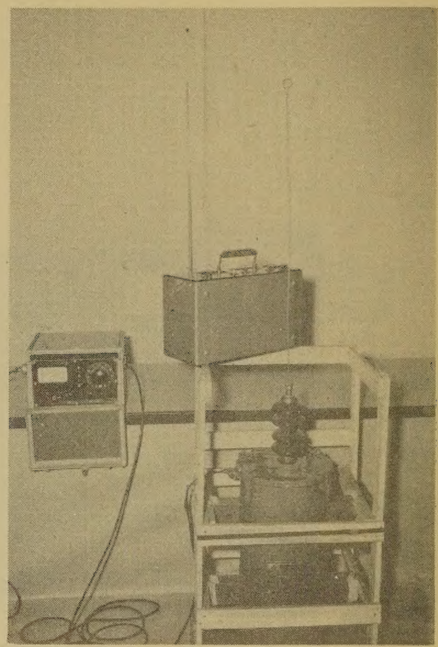

Figure 10. Transformer test setup.

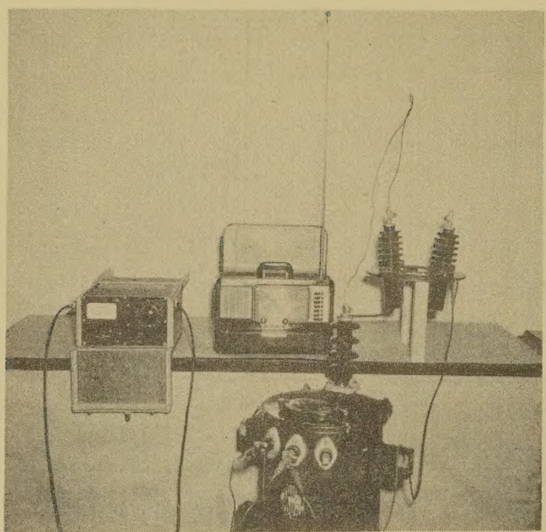

Figure 11. Transformer bushing test setup.

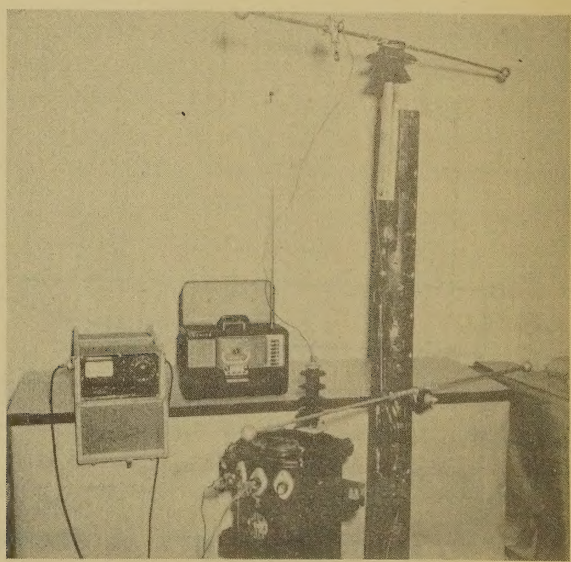

Figure 12. Pole top assembly test setup.

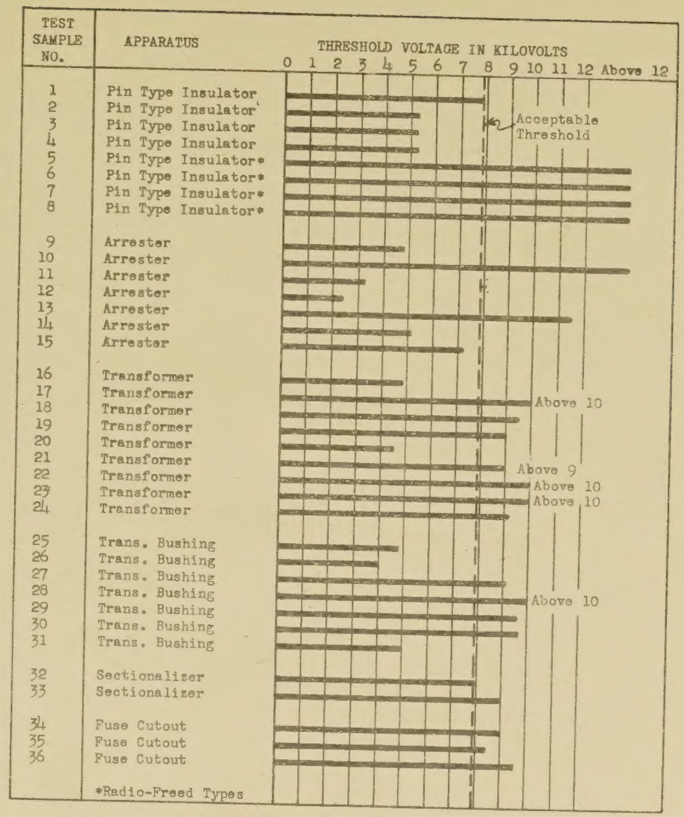

Figure 13. Typical ionization threshold voltages of apparatus designed for use on 7.2/12.5 kv grounded wye circuits.

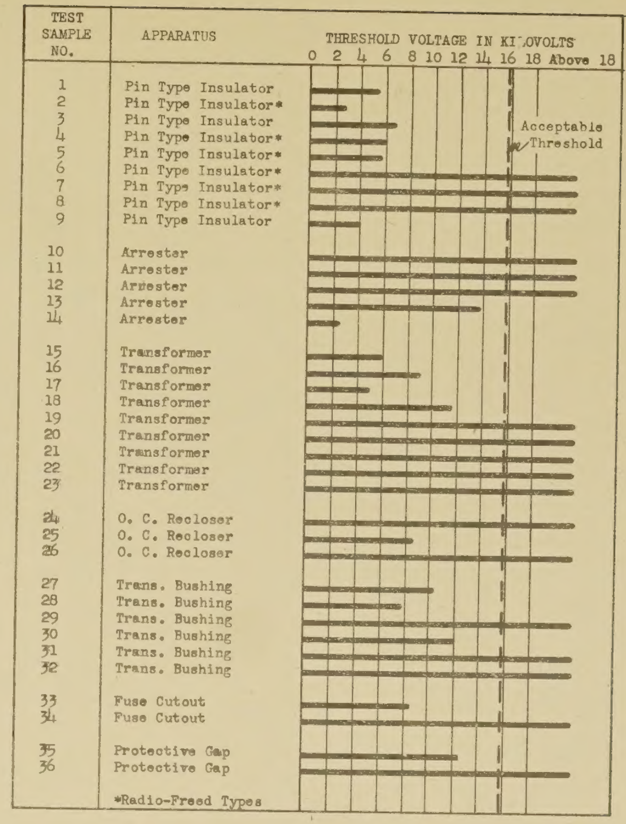

Figure 14. Typical ionization threshold voltages of apparatus designed for use on 14.4/24.9 kv grounded wye circuits.